55 Mine-Wide SCADA System

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The Xstrata Nickel Rim South (NRS) mine is located northeast of Sudbury on the eastern rim of the Sudbury basin. Initially discovered in 2001, the confirmed resource has grown to 17.4 million tons. This is roughly evenly split between a contact zone containing 2% Nickel and a footwall zone containing 5% copper and high in precious metals. A view of the mine-site is shown in Figure 55.1.

Mine construction started in 2004, leading to the first production blast occurring in May of 2009. During this time, the project sank two shafts, installed all major mine infrastructure, and achieved 5.7 million hours without a lost time injury. Full mine production capacity is 1.25 million tons per year.

The two ore bodies are close enough to be serviced by one main shaft (used as the fresh air intake) and one ventilation shaft (used for return air). Both shafts reach to a depth of 1750 m, with stope access being from three main levels with internal ramp access to the producing stopes as noted in Figure 55.2. The ore body is mined using the blasthole mining method. In the full mine, ore will be transferred using diesel powered scoops from working stopes to two sets of three underground bins transferring to loading pockets at the 1,520 and 1,700 m levels.

TECHNOLOGY STRATEGY

There have been many advances and innovations in technology in recent years that offer the potential to monitor and control mining processes. This has been a long-time strategy for the fixed plant portion of the processes where ore/waste handling systems have been automated for years and the production data automatically collected. However, these efforts have not been part of an overall strategy and have not necessarily considered integration of all mine systems. For NRS, Xstrata Nickel recognized the opportunity to make a step change in the visualization of the entire mining plant. The drive to view NRS mine as a process, similar to a surface metallurgical plant, is the long-term vision of this strategy. The following strategy statement was adopted, which formed the basis for all applications of technology:

> Nickel Rim South Mine is committed to implementing and sustaining the next level of technology. Proven technical systems will be applied to their full potential where improvements can easily be demonstrated in the areas of safety, production, productivity and reliability. As part of this commitment, employees will be engaged and educated in technology to foster an environment of high technical skill and continuous technical improvement.

It is this strategy that has led to the world-class supervisory, control and data acquisition (SCADA) system installed at NRS mine.

TECHNOLOGY VISION

The above strategy resulted into a vision for the mine, which included the following elements:

1. Mine-wide communications system infrastructure
2. Mine-wide SCADA system
3. Self-regulating mine system control

Mine-Wide Communications System Infrastructure

The concept of automatic collection of production and maintenance data as well as real-time access to this data, required a seamless communications infrastructure that would link activities at the working face to the various mine information systems. Traditionally, this would have been performed by installation of various separate systems for voice, video, data, remote control, tracking, and data acquisition. These systems would all be "owned" and maintained by different mine departments as appropriate. The problem with this approach has been found to be that some systems inevitably become identified as more critical than others (e.g., leaky feeder for voice) and over time, resources are diverted from the other systems. This may ultimately lead to the "less critical" systems being neglected to the point that they, and the system that relies on them, can fail.

In the case of Nickel Rim, a single communications backbone, which would provide for all communication requirements, was selected. While this may be seen as a case of "all eggs in one basket," it has the advantage of requiring a less diverse system of resources to maintain, and assures it getting the attention it requires owing to its critical nature.

The selected communications backbone is the Ethernet. It is comprised of both wired (fiber-optic and copper) as well as wireless infrastructure. As indicated in Figure 55.3, this

FIG. 55.1
Nickel Rim South Mine—Sudbury, Ontario.

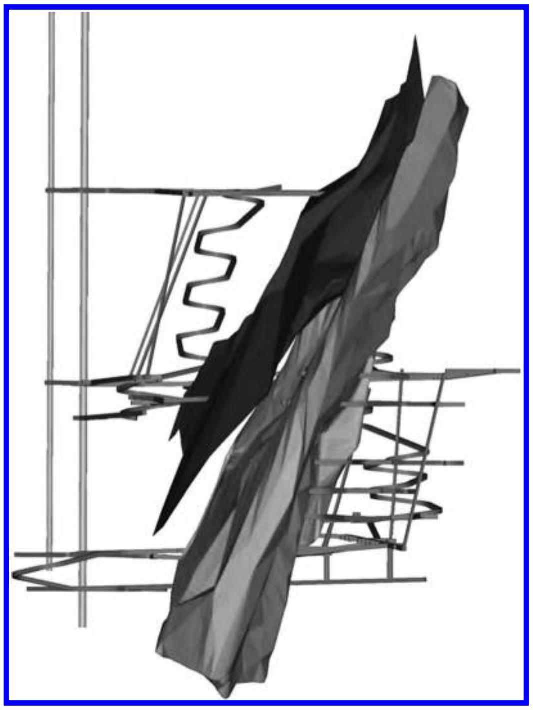


FIG. 55.2
Mine longitudinal section showing three main access levels.

infrastructure supports communication between all mine systems, both surface and underground. In fact, it allows mobile underground equipment the same level of access in terms of SCADA as permanent fixed plant equipment. Using this approach, there are fewer issues with integrating different networks and different systems.

Mine-Wide SCADA System

The vision for Nickel Rim mine included an operations center (OC). The primary function of this OC is to host the controls for the four hoists. A single hoistman occupies the OC. While all hoists are automated, regular manual operation is required for maintenance and other activities. This hoistman is thus available to respond when intervention is required on other mine systems, but *cannot be distracted while operating the hoist*. This required the implementation of a "High Performance" SCADA system, which allowed visualization and control of site operations with the minimum of effort and surveillance.

The above prompted the installation of a large "process overview" display, which allows for "mine status visualization at a glance." The overview display indicates unambiguously whether operator intervention is required on a particular process system. Audible alarms generated by this system indicate that an action is required, which cannot be performed by the automation system. The priority of these alarms indicates how quickly this action is necessary. The role of the OC operator (hoistman) is not to scan the process to ensure that all is ok. The system is designed to indicate when intervention is required.

In addition to the human–machine interfaces (HMI) located in the OC, local HMI displays are required to be located at various locations, both at the surface and at the underground. While most of these are fixed, some are mobile and have to be wirelessly connected to the data sources and HMI server. The vision here is to make the data required by a worker available at the workplace. This is a step away from the centralized model of control where all operation is performed from a central control room. Why force a worker to leave his workplace or contact someone else to get the information required, when the mine-wide communications backbone can deliver such information directly to the worker?

Self-Regulating Mine System Controls

In order to achieve the vision of mine systems that run themselves without the requirements of constant supervision, the control system has to be sufficiently powerful to allow the configuration of advanced controls, which can be easily operated and troubleshot.

In order to achieve this, the system has to allow a layered approach to process controls to be achieved. Control is implemented following the classical control hierarchy. This is in order to ensure that each layer of optimizing control is built on a robust underlying layer. As illustrated in Figure 55.4, each layer of the control system provides an increasing level of optimization (levels 1–5). There is an increasing level of complexity associated with operating at these higher levels of optimization. This complexity negatively effects robustness, and it is imperative that the underlying level of control is available to "take control" when a system error prevents operation at a more highly optimized level.

By structuring the various control strategies in this way, one avoids an "all or nothing" scenario, where a minor subsystem failure prevents any form of automatic control from operating. If structured as in Figure 55.4, in the case of some failure, one merely reverts to a more basic level of control, which is still optimized from the base case.

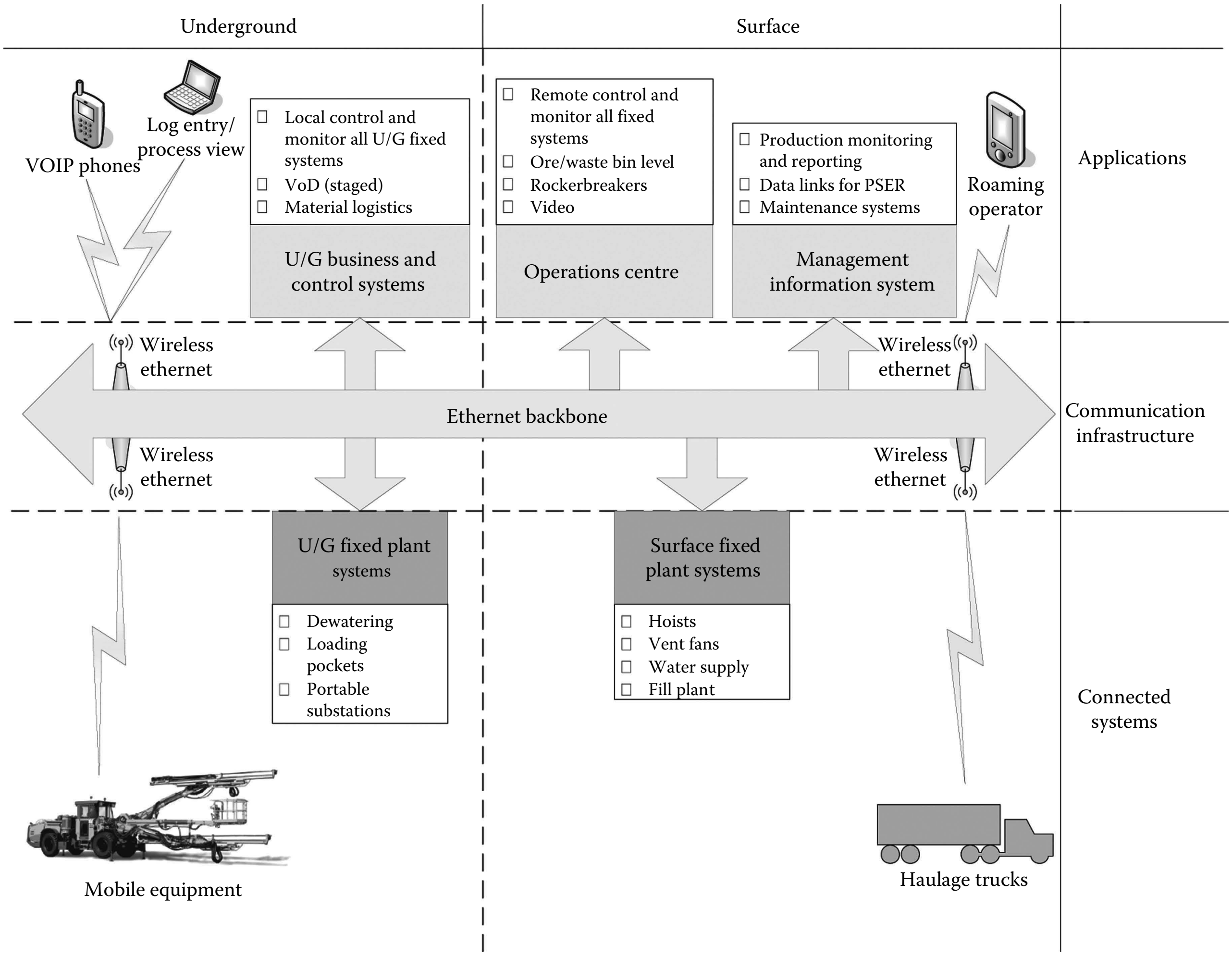


FIG. 55.3
Applications using communications backbone infrastructure.

DESIGN CRITERIA

The technology vision resulted in the following SCADA system design criteria:

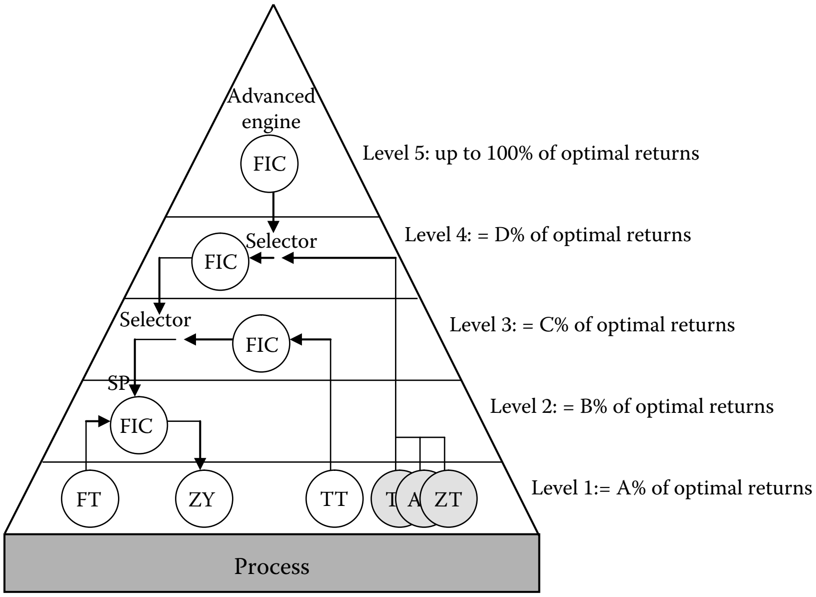
1. Integrating control systems and motor control centers (MCC)
2. Remote administration (diagnostic, programming, configuration) capabilities
3. Programming to follow IEC-61131-3 specification

Integrated Control Systems and Motor Control Centers

Since substation automation was included in the scope for mine automation, it was desirous to be able to integrate all MCC components (starters, overload relays, ground fault relays, etc.) directly into the control system. The alternative (and traditional) means is to hard wire all MCC components via the input/output (I/O) cards. This is not only costly in terms of I/O cards, labor, and panel space but limits what information can be collected to those signals that are physically connected. By interfacing all MCC components to the control system via a communications link, a single connection can transfer thousands of data points.

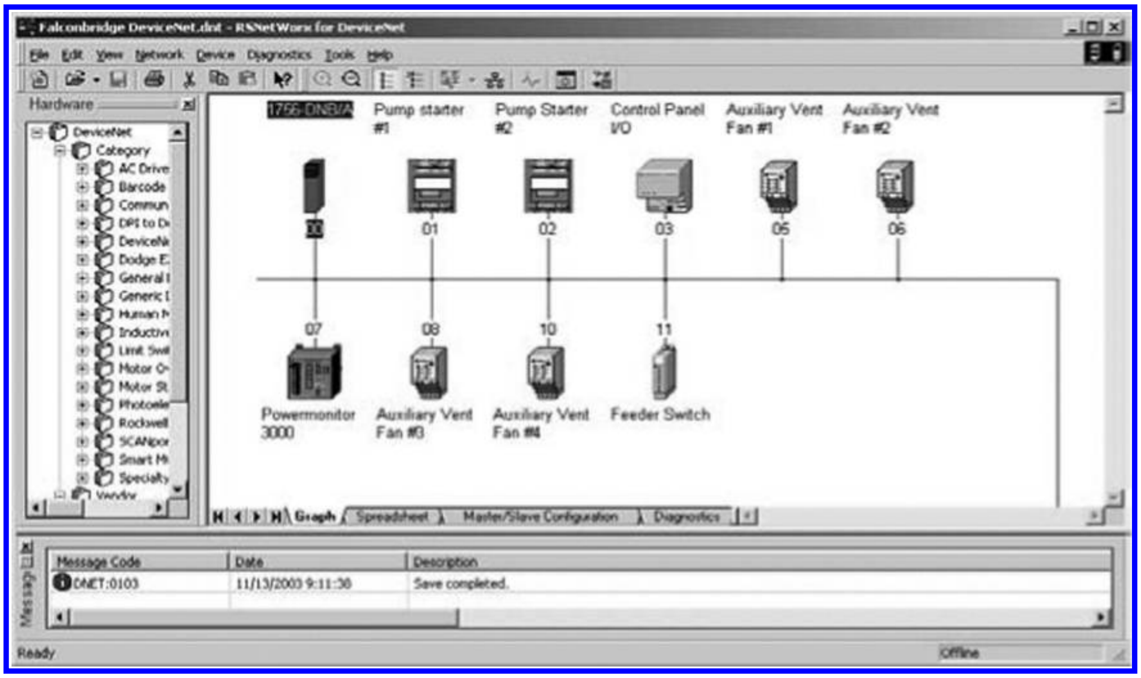
By maximizing the types of electrical data that can be transmitted from the substations, the potential to use this information to affect process control strategy is extended. Process control strategies can be developed, which use the full range of power data, in order to optimize the control strategy. Examples of this could be energy management or power factor optimization.

DeviceNet was selected as the above-mentioned communication bus. By selecting “intelligent” MCC components and having them all connected to DeviceNet, it was possible to integrate them directly into the rest of the control system. This also allowed remote diagnostics and configuration using appropriate software tools (as indicated in Figure 55.5). This can be done remotely from surface, which allows diagnostics and appropriate spare parts to be prepared before planning underground maintenance activities.


Advanced engine
FIC
Level 5: up to 100% of optimal returns
Selector
FIC
Level 4: = D% of optimal returns
Selector
FIC
Level 3: = C% of optimal returns
SP
FIC
Level 2: = B% of optimal returns
FT
ZY
TT
T
A
ZT
Level 1:= A% of optimal returns
Process

Note: 100% > D > C > B > A. Precise values are dependant on the effectiveness of each control

FIG. 55.4
Classical control hierarchy (flow control example).



Message Code	Date	Description
DNET:0103	11/13/2003 9:11:30	Save completed.

Ready

Offline

FIG. 55.5
DeviceNet software identifies all MCC components automatically.

Programming to Follow IEC-61131-3 Specification

IEC-61131 defines five standard languages for automation programming; each of which is suitable for a particular automation task:

1. *Ladder logic*: The "original" PLC programming language that gained traction since it is analogous to electrical wiring diagrams and hence suitable for discrete control (motor start/stop) and interlocking processes. It has been adapted for continuous control processes, but become difficult to read as they get more complex.
2. *Function block*: This method of programming deploys standard functions (e.g., counters, PID blocks, etc.)

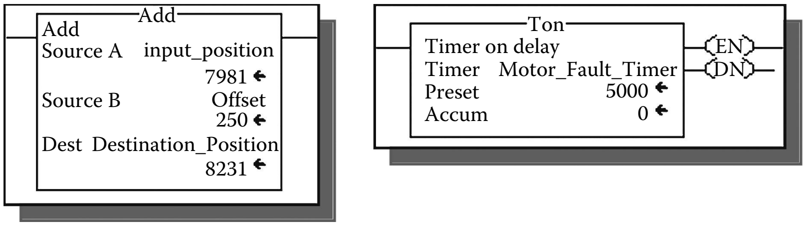


FIG. 55.6

Examples of standard function blocks (addition and timer—delay ON).

as "objects" defined by their respective I/Os. These inputs and outputs are linked together to produce a graphical result, which describes the control strategy. This graphical nature is "user friendly," which makes it suitable for development and maintenance of more complex strategies.

3. *Sequential function chart (SFC)*: For sequential processes that require execution of control actions according to a "recipe." Process execution is according to a series of events. SFC contains the structure required to manage that sequential nature of code execution, which would otherwise have to be created if using one of the other five languages.
4. *Statement list*: Synonymous with processor assembly code, this low-level language is suitable for intensive bit manipulation and applications that require maximum performance and low-level discrete control.
5. *Structured text*: This represent a high-level programming language where control logic is programmed using syntax similar to that of Visual Basic or C. Often used for computational functions since expressions can be entered in their natural form.

The advantages of utilizing a programming tool that supports the above languages are as follows:

1. *Delivers "DCS like" functionality to a PLC system*: By being able to program in a language that suits the automation task, the processing power of PLCs can be used for continuous control and computational processes. Programming complex continuous control processes in ladder logic is possible, but the results are extremely difficult to interpret and hence subsequently maintain. As an example, the author has been able to program real-time computation of the *standard deviation* of a process variable, using only six lines of (structured text) code. This would be extremely complex to achieve in a control system that only supported ladder logic.
2. *Allows "object orientated" programming*: Basic function library blocks (timers, logic blocks, etc.) can be used to create more complex functions (e.g., enhanced PID controllers) or custom functions to suit local equipment (e.g., conveyor start/stop including start-up siren). These complex functions can then be represented symbolically (in terms of input and outputs only), and be reused many times; appearing much like a 'standard' functional block (Figure 55.6). Any complexity within the code is 'hidden' from the user, which makes deployment and troubleshooting easier. This "black-box" (object) approach requires only the appropriate inputs and output to be configured. Such "object orientated" programming is what allows high-level programming languages such a Visual Basic or C, to achieve very powerful results.
3. *Code is more structured, readable, and maintainable*: Since the programming language now suits the process being programmed. In this way, multiple pages of code encapsulated in "user-defined" function (as in Figure 55.7) which can be reused. Programs can be self-documenting, reducing the requirements for additional documentation.

Remote Administration (Diagnostic, Programming, Configuration) Capabilities

Traditional SCADA systems comprise of at least one server that hosts data communications, HMI, and other SCADA functions. HMI clients (operator screens) would typically run on remote computers, which will require installation of a suite of communications and other software as well as any required software licenses. Each of these computers will also require installation of an operating system, antivirus software, etc., and will require software patches throughout its lifetime. Every additional operator station thus needs significant setup and administration effort. Inevitable failure of the PC will require a time-consuming rebuild.

Depicted in Figure 55.8, this architecture is both hardware and software intensive and becomes onerous to administer, particularly as the system grows. Keeping the system updated is challenging since each operator station is a full-blown computer. These computers may be distributed over a large area; some in demanding environments where despite using hardened "industrial" hardware, failure is more often a case of "when" than "if."

Thin-client architecture simplifies the architecture depicted in Figure 55.8 by replacing all operator screens with "Thin Clients." Thin clients are basically computers that have been "stripped down" to support only minimum functionality. They are typically fanless with solid-state hard disks. This removes the components that are most prone to failure

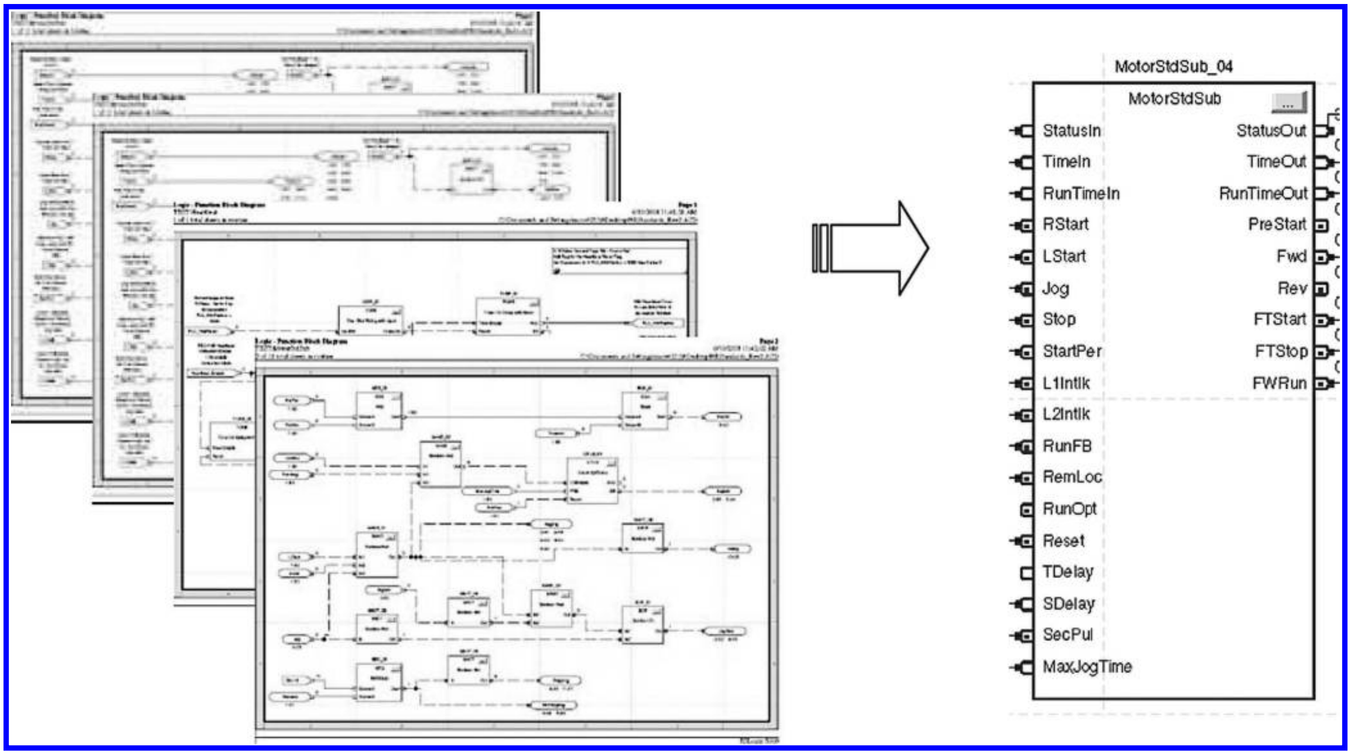


FIG. 55.7
Multiple pages of "User-defined" functions.

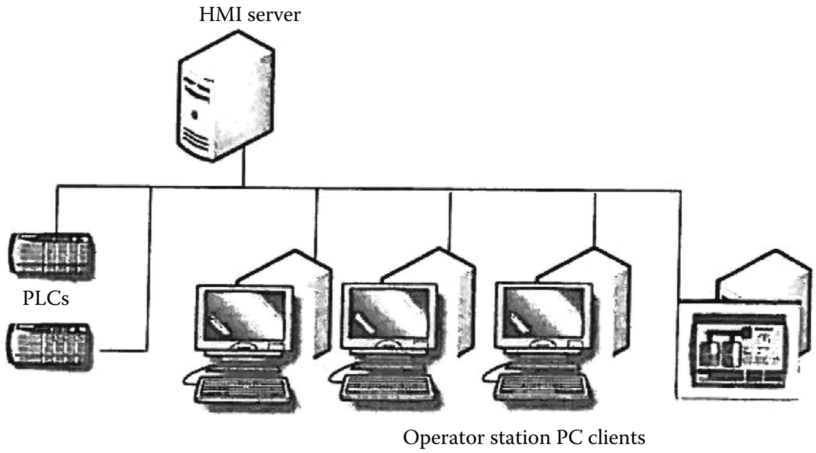


FIG. 55.8
Traditional SCADA system architecture.

in standard computers. The operating system may also be simplified to support only minimal functions (e.g., Windows CE). In the case of the SCADA architecture depicted in Figure 55.9, the only functional requirement is support for a Windows remote desktop protocol (RDP) connection.

In this architecture, all HMI client software is installed on a single terminal server, (multiple terminal servers can be deployed if redundancy is required). Upon "power-up," each thin-client operator station automatically logs into the terminal server and the HMI software is launched on the terminal server. Because it is a terminal server, all HMI sessions run concurrently, each independent of each other.

Motivations for this architecture are based on *lower total cost of ownership*. This is brought about by

1. Remote administration capabilities that is focused on a limited numbers of servers. All clients are essentially "dumb"; all software being resident on the servers.
2. Security efforts can be focused on a few (securely located) servers. Thin clients do generally not require

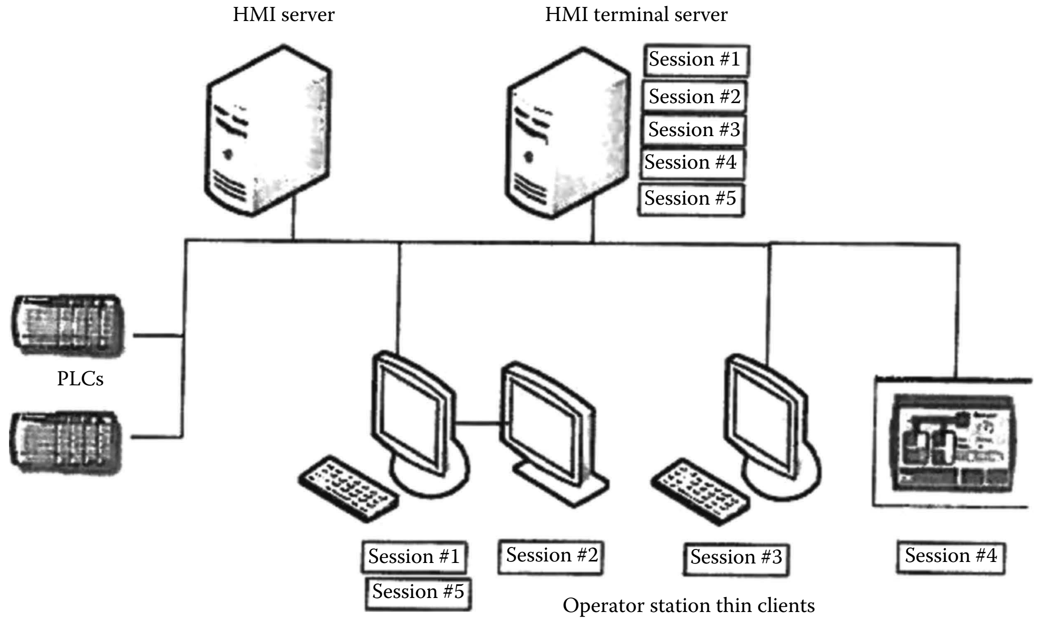


FIG. 55.9
Thin-client SCADA architecture.

security patching or antivirus software. Only the servers require to be protected.

3. Rationalized hardware inventory brought about by thin clients replacing that would otherwise be full standalone computers. Operator stations, which have failed, can be replaced by "out-of-the-box systems," since no software is required to be installed on these stations.
4. Reduced system development overhead since once changes are completed on the HMI server, they are instantly available on all operator stations (all HMIs are in effect on one box). On traditional systems, changes would be required to be distributed across the network of operator stations.
5. Thin-client operator stations do not necessarily have to be limited to displaying HMI only. Because multiple RDP sessions can be launched simultaneously without excessive load on the client, the screen can be used for additional purposes if required. Access to all required software applications (e.g., reports, microseismic system, email, etc.) is possible from a single client reducing the number of screens required. In Figure 55.9, for example, "Session 5" could provide direct access to the mine energy management system.

There will typically be several persons who require access to parts of the SCADA system in order to perform development and maintenance duties. Access to the various automation software tools is traditionally provided by installing this software (including licenses) on a number of computers (often laptop), which are then shared by the maintenance persons. These units may often be brought into the field and are thus subject to a high rate of failure. Replacement of these machines requires reinstallation of software and licenses; a process that may be particularly onerous owing to licensing and software update issues. Furthermore, access to the above software platforms is often through shared user accounts (e.g., users "Admin" or "Tech") with widely known passwords. This represents not only a security risk, but makes it impossible to implement audit trails for system access and changes, since multiple users use the same credentials.

The terminal server architecture indicated in Figure 55.9 can be further applied to address the above SCADA system administration issues. By replacing all the above mentioned "engineering/configuration" machines with a single (or redundant) Engineering Workstation (EWS), one can *centralize* the location of all the software tools required to support the system. By making this server a terminal server, multiple persons can log into the EWS simultaneously and launch any software required to perform the support task. Change management software tracks changes to system configuration and performs system backup functions automatically.

Examples of the system administration tools deployed on the Nickel Rim EWS are as follows:

- PLC programming software (RSLogix5000)
- Data communication software (OPC & RSLinx Gateway)
- DeviceNet communication software
- System change management software (Assetmanager)
- UPS monitoring tools
- Ethernet monitoring tools
- Drawings, manuals, and other documentation

Because all that is needed to access the EWS is an RDP client, the above-mentioned "engineering laptops" can be replaced by low-cost mobile thin clients or tablets with no "local" software installed. These thin clients are typically diskless and fanless and thus more likely to be durable. In the case of failure, a replacement will perform the same duty "out-of-the-box" without having to install any SCADA system software and licenses.

Furthermore, by replacing the above-mentioned "shared" system access accounts with personal (domain based) accounts, the security issue is addressed. By granting these "personal" accounts the appropriate rights, the SCADA system access privileges can be carried by the maintenance person to any place on the network that has the required connectivity to the SCADA system. This extends the concept of the roaming operator to that of a roaming system support technician.

PLANT VISUALIZATION STANDARDS

Evolution of HMI

Typically, HMI displays are designed with the expectation that a skilled operator who is familiar with the process continually scans the displays. This is born out of historical control rooms where all plant information was displayed on a wall containing indicators, charts, lights, and alarm panels (Figure 55.10). Over and above the issues with maintaining and developing these display walls, they had the following disadvantages:

- *Operator had to "baby-sit" the process*: It was only through experience that "seasoned" operators became comfortable with operating the plant. This "feeling" for the plant was difficult to transfer to others without them going through the same time-consuming and costly experiences.
- *No hierarchy in the display of information*: While parts of the wall may have been grouped together, here was little attempt to summarize key performance indicators (KPIs) and little to no potential to mask out superfluous information during fault or loss of production conditions.
- *Difficulties when thing went wrong*: Partially from the fact that information and controls were spread out physically, but also because there was no way of summarizing information or presenting context sensitive alarms.

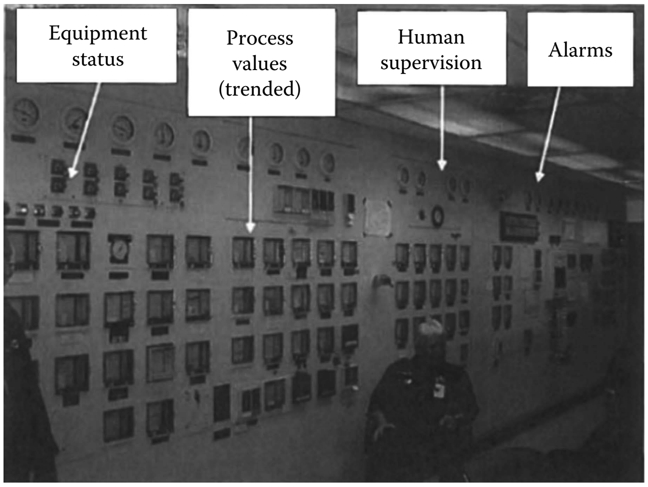


FIG. 55.10

Legacy plant control room. (Reproduced from Bill, R.H. et al., The High-Performance HMI Handbook, PAS (www.pas.com), ISBN 978-0-9778969-1-2, p. 10. With permission.)

With the advent of commercial computer technology, the above process status displays were transferred to process computer screens as indicated in Figure 55.11. While this was an obvious advantage in terms of simplifying the hard-wired control wall systems and associated mechanical components, it did little to improve the way the process was displayed. Many of the disadvantages above remained unchanged. The graphical images were mostly still merely representations of the process and instrumentation diagrams (P&ID) with colors chosen haphazardly.

There was an attempt to establish a standard for Nickel Rim early in the SCADA development phase, but over time it became apparent that these standards were based on existing practice, a variety of ideas, and not necessarily "best practice." This became apparent once the first production systems were being commissioned when it was found that the hoistman had to "baby-sit" the production hoist in order to ensure that it was operating efficiently.

Since the primary function of the hoistman is to operate the hoist controls as required, the requirement for "at a glance" system diagnosis became apparent. There is no opportunity for the hoistman to "scan" the process since this would potentially cause a distraction from other duties. The HMI *had to* indicate unambiguously when intervention is required.

High-Performance Visualization Techniques

Arising from incidents in the petrochemical industry, where unaddressed process failures have led to catastrophic results, high-performance visualization techniques have been developed. These techniques can improve process operator response to deviant conditions. Such "High-Performance HMI" design expertise and advice was supplied by a company called PAS from Houston, Texas (*www.pas.com*). Particular attention was paid for user- and operator-friendly features of the HMI displays as exemplified in Figure 55.12. The left-hand figure is an indication of a compressor system with real-time condition monitoring parameters indicated. The same information is represented in the right-hand side in a bar graph format showing normal ranges. Deviation is further indicated through color and shape; both indicating the severity of the deviation. It is obvious the right-hand representation is more intuitive and allows for rapid interpretation.

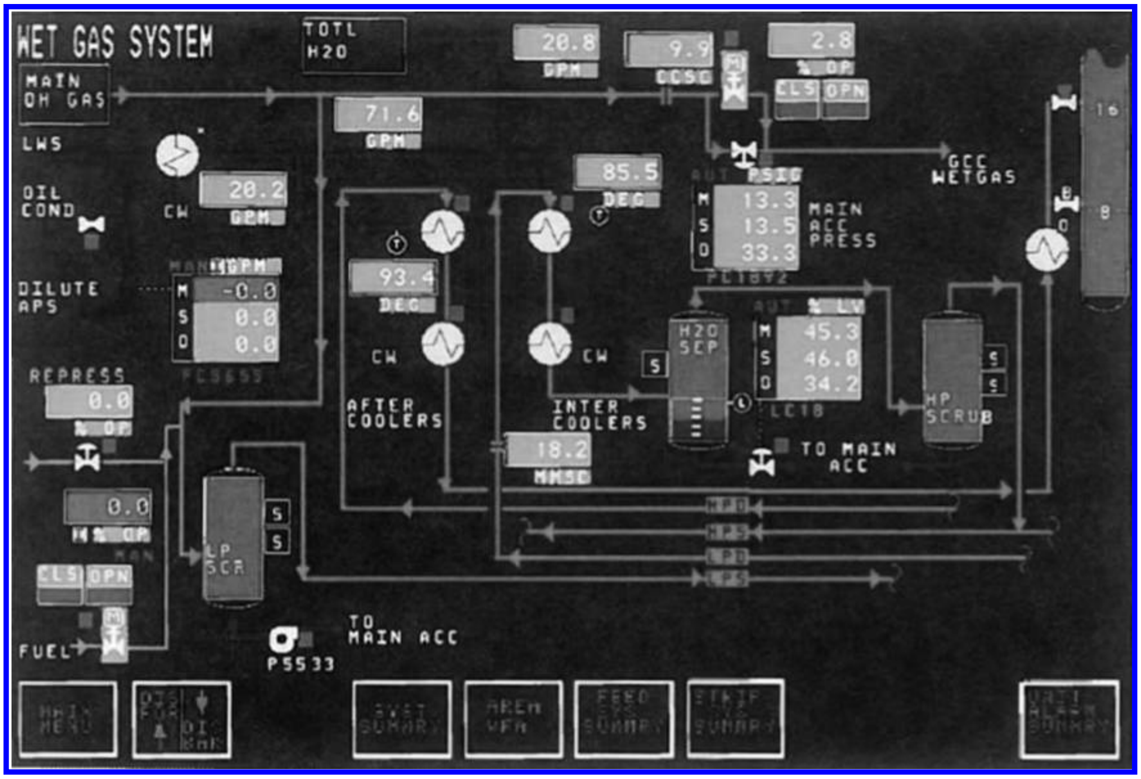


FIG. 55.11
Computer-based process status display. (Reproduced from Bill, R.H. et al., The High-Performance HMI Handbook, PAS (www.pas.com), ISBN 978-0-9778969-1-2, p. 10. With permission.)

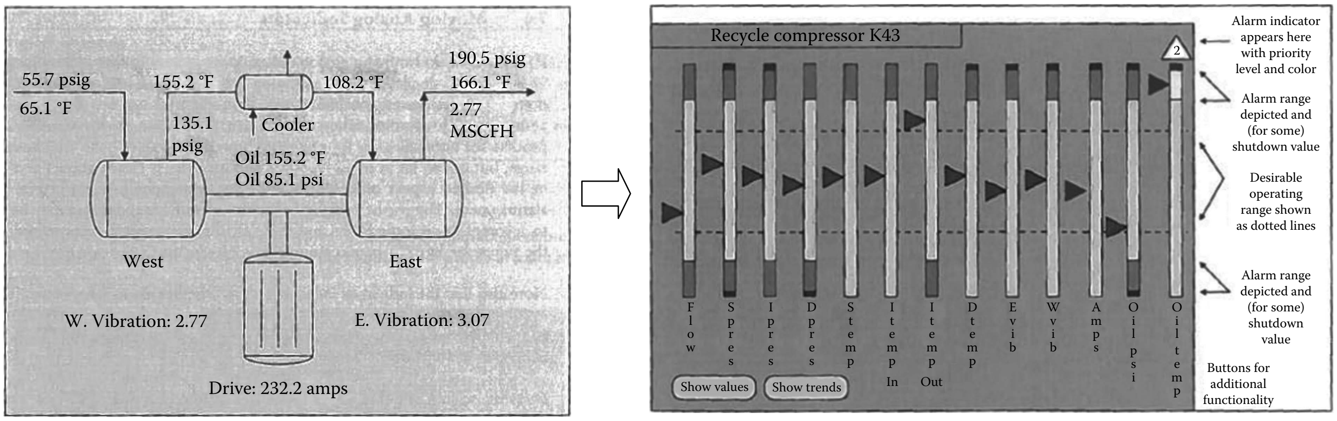


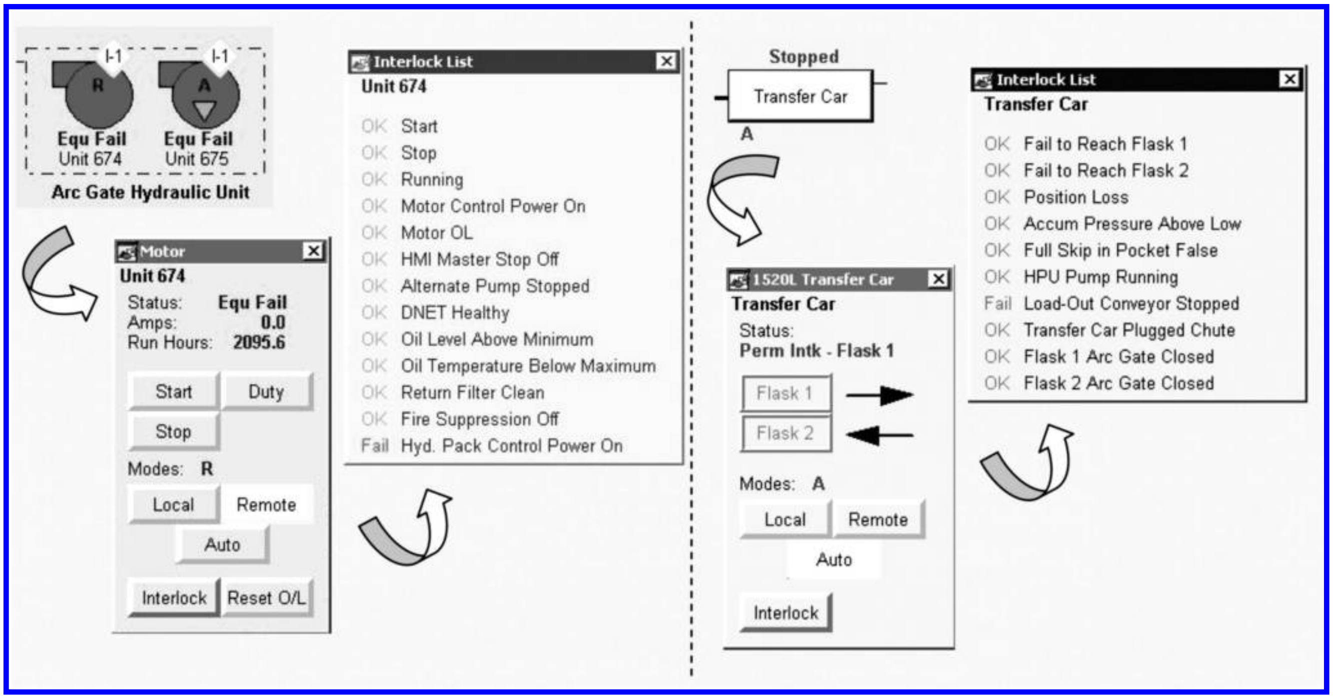
FIG. 55.12
High-Performance compressor visualization. (Reproduced from Bill, R.H. et al., The High-Performance HMI Handbook, PAS (www.pas.com), ISBN 978-0-9778969-1-2, p. 10. With permission.)

"Best Practice"–Based HMI Display Standard

The following visualization philosophies were applied in creating the NRS SCADA standards.

Colors That Are Reserved for Alarms Not to Be Used Elsewhere "Red" is a color universally used to indicate a hazard or alarm and this standard should be retained. If alarm priority levels are required, other colors may be reserved. Once these colors are selected, they should not be used for any other purpose. This may sound obvious, but its a principle ignored by the vast majority of SCADA systems in existence; where red is used to indicate ON (or OFF) status.

Take the typical example where red is used to indicate that a pump is stopped. This may be the desired status for a series of pumps displayed on an operator screen. Should a high-priority alarm condition now appear (in red) in the same display, it will be less obvious owing to excessive use of



Unit 674
Status: Equ Fail
Amps: 0.0
Run Hours: 2095.6
Modes: R

Interlock List
Unit 674
OK Start
OK Stop
OK Running
OK Motor Control Power On
OK Motor OL
OK HMI Master Stop Off
OK Alternate Pump Stopped
OK DNET Healthy
OK Oil Level Above Minimum
OK Oil Temperature Below Maximum
OK Return Filter Clean
OK Fire Suppression Off
Fail Hyd. Pack Control Power On

Transfer Car
Status:
Perm Intk - Flask 1
Modes: A

Interlock List
Transfer Car
OK Fail to Reach Flask 1
OK Fail to Reach Flask 2
OK Position Loss
OK Accum Pressure Above Low
OK Full Skip in Pocket False
OK HPU Pump Running
Fail Load-Out Conveyor Stopped
OK Transfer Car Plugged Chute
OK Flask 1 Arc Gate Closed
OK Flask 2 Arc Gate Closed

FIG. 55.13
Example of standard display elements and detail faceplates.

the same color to represent what is a "normal" condition. By using the same color for alarm and status indication, we have introduced the requirement to inspect and interpret in order to judge whether action is required. This subjectiveness may lead to a poor decision particularly during high stress conditions, and is not consistent with "plant status at a glance."

Use Color and Shape to Indicate Alarms and Status Notwithstanding the practice of using only reserved colors to indicate alarms or deviant conditions, there is the chance that color may be poorly interpreted by some individuals. This requires that shape should also be used to indicate alarms and status. Text is a valid example of use of shape. Changing the color of displayed text or process variable achieves this objective.

Displays Generally Gray Scale In order to achieve the vision of with "plant status at a glance," the baseline "all ok" status should be immediately obvious; requiring no inspection of the display. This is best achieved by representing all the display elements in gray scale. This makes the use of color to describe process deviations that require attention more obvious to the observer. This is exemplified in Figure 55.13, which shows a standard display elements and detail faceplates, e.g., for pump and transfer car.

Use Standard Display Elements HMI systems have developed powerful graphics development engines. It is now easily possible to create near three-dimensional representations of plant processes. For representing a process as accurately as possible, HMI designers may even use a photographic image of the process being controlled and superimpose the process data at the various locations. While this may look impressive to observers and may reenforce the expectation that money spent on the SCADA system has been justified, the truth is that this wears off very quickly on the operator who is concerned with information, not glossy looks.

The ability to visually represent plant equipment in a visually accurate way is superfluous. With few exceptions, a pump is a pump; a valve is a valve, etc. All functionally similar equipment should therefore be represented similarly in order that available controls and indications are presented in a similar manner.

Status Displayed Uniformly As indicated in Figure 55.14, all display elements (pumps, valves, conveyors, etc.) should display status uniformly.

Minimize Animation Animation should not be used to indicate equipment status information. Attempts to indicate pump rotation, conveyor motion, etc., may be initially impressive, but add no value to process operations. Using system resources for this purpose may in fact degrade system performance and hence have a negative effect on process operation.

Animation may be useful when equipment *position* is significant and can be updated effectively on the operator screen.

Limited Static or Redundant Information Static or background display elements (lines, boxes, and other shapes) may be useful to place the equipment depicted in context in

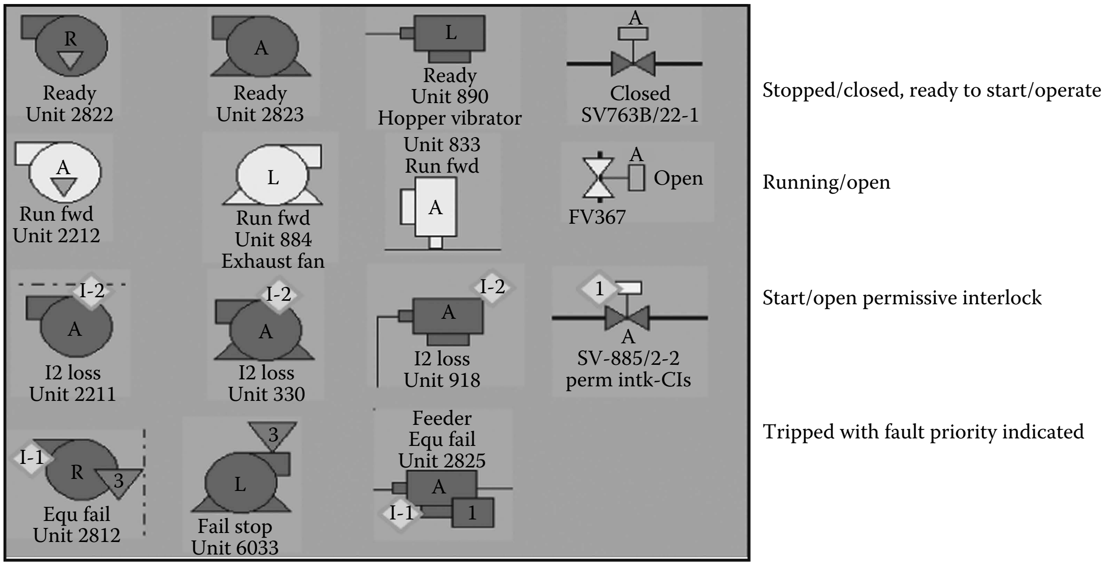


FIG. 55.14
Status indication of pumps, fans, motors, and valves.

relation to each other. Process flow is important and should be indicated without resorting to visually realistic graphics.

Text communicating caution or clarifying equipment operation should be limited to separate displays rather than being depicted statically on the operator display. Actions that may result in critical consequences should be confirmed using a pop-up display drawing appropriate attention to these consequences.

Alarms

Process alarms are the means by which the SCADA system indicates to the process operator that intervention is required. Alarm management expertise and advice was supplied by the PAS Company, Houston, Texas. The resulting philosophies resulted in the development of an alarm standard for Nickel Rim.

An Alarm Must Always Result in a Corrective Operator Response Deviant conditions that result in an automated response should not be alarmed. An example of this would be a high tank level that results in pump being started. The high level itself is clearly not an alarm. Failure of the pump to start, or a subsequent high-high level would however both be valid alarms, since a corrective action that cannot be taken by the SCADA system is required.

Alarms Should Be Conditioned according to Equipment Status If an alarm condition is only valid under certain plant status conditions, these status conditions should be used to enable and disable the alarm. An example of this would be a "low flow" alarm on a pump discharge. The alarm should be enabled only when the pump is running. Should the pump be stopped, the low flow alarm should be disabled since it is expected and will not require a corrective action by the operator. Should the pump trip under normal operation, the alarm generated should be "pump tripped" and not the consequent result of "low flow."

The above philosophy serves to avoid *standing alarms* (alarms that appear statically on the alarm display and require no action) and *multiple alarm*s all resulting from a single event. A pump trip may result in low flow and low pressure, which should not be alarmed since they are a consequence of the pump tripped event. They are only valid if they occur when the pump is running.

Define Alarm Priority in Terms of "Maximum Time for Operator Response" Definition of alarm priority is notoriously subjective since the concept of importance is dependent on the perspective of the observer. As indicated in Figure 55.15, defining priority as "Maximum time to response before safety/production is affected," significantly clarifies the classification.

Alarms Should Be Filterable by Priority and Process Area During critical periods, which may produce alarm

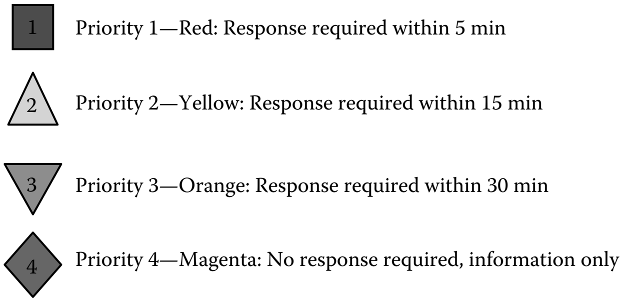

1
Priority 1—Red: Response required within 5 min
2
Priority 2—Yellow: Response required within 15 min
3
Priority 3—Orange: Response required within 30 min
4
Priority 4—Magenta: No response required, information only

FIG. 55.15
Alarm priorities and associated colors and shapes.

"floods," it is important that alarms can be sorted to allow more critical issues to be dealt with first. Having separate alarm overview displays for different process areas can further assist in communicating which process areas require attention.

An extension of the filtration philosophy is the concept of "alarm shelving." This is the process by which nuisance alarms can be disabled temporarily, in order to avoid these alarms from distracting the process operator from other valid alarms. Due care and process are required when implementing such a system since there may potentially be serious consequences arising from disabling alarms.

MINE SYSTEM VISUALIZATION

Process visualization displays can be categorized into three levels:

Level 1: These are overview displays that display entire processes from a high level only. They typically show only critical data, which is required to indicate status of the area. They are often used to navigate to a particular part of the process, through mouse clicking on a particular area of the display.

Level 2: This display will show the details of a particular process, but may still neglect the entire picture of a subsystem such as the detailed running status of a variable-speed drive or lubrication system. The process is typically operated from such a display.

Level 3: These displays show the highest level of details and may be used to diagnose a problem, once the location where the problem has risen and has been identified. Examples may include detailed condition information of a motor such as winding and bearing temperatures as well as vibration data.

Operations Center Overview Display

The Nickel Rim mine is equipped with an OC. The OC is centered on a large 2.5 m × 2 m LCD display that is used as the level 1 process display as shown in Figure 55.16. The purpose of this is as follows:

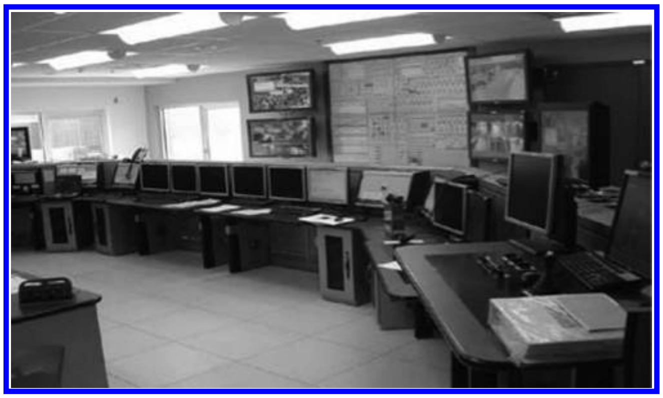


FIG. 55.16
Nickel Rim South Operations Center.

Display the Process "at a Glance" This not intended to be "scanned" by the operator. Adherence to the principles described above allows the operator to determine mine status at a glance.

Overview the Display This the primary communicator of deviant process issues that require manual intervention. A process alarm is indicated on the overview display (using color and shape) and can be drilled down and investigated on the level 2 and 3 displays available in front of the operator.

Indicator of Past, Current, and Projected Plant Performance This is performed through visualization of KPIs. They may be related to production, safety, efficiency, or environmental targets.

The overview display (Figure 55.17) appears overcrowded and complex at first, but if it should be remembered that it is not intended to be "scanned" without even focusing the eye, the areas where attention is required is obvious. This is made possible by adhering to the visualization techniques discussed above. Specific visualization techniques utilized in the overview display are discussed below:

Current Production Performance Mine production targets for each day are indicated on a table in Figure 55.18. Performance against these targets is indicated by a bar that progressively moves from left to right during the course of the day. At hours 12 of a 24 h period, it will thus cover 50% of the bar indicating that 50% of the target should have been reached.

Actual production is represented by the indicator below the bar. If behind target, the indicator will be left of the bar, and if ahead of production the indicator will be right of the bar.

Surface Ventilation System Status Status of critical equipment can effectively be represented in a table if such a table does not need to be inspected. This is accomplished if deviant conditions are represented by color and shape. Normal conditions would thus be indicated by the lack of these colors and shapes. In the example in Figure 55.19, a diagnostic fault is present in intake fan two (although the fan is still running at this stage). The priority of three indicates that the operator has up to 30 min to respond to this alarm.

The black border around the "Mode" status of the West Exhaust Fan indicates that the fan is running in manual. This may be a valid condition depending on activities at the time and as such does not constitute an alarm. The highlighted border does however designate this condition as "unusual" and is obvious "at a glance."

Inventory Tracking Current inventory level is best represented by indicating past and present values. This has been traditionally accomplished by using a trend display object showing the value for an appropriate period of time into the past. However, this trend can be extended into the future by using a variety of techniques. This gives the process operator the opportunity to see where the process is heading, without having to make this evaluation through his own analysis.

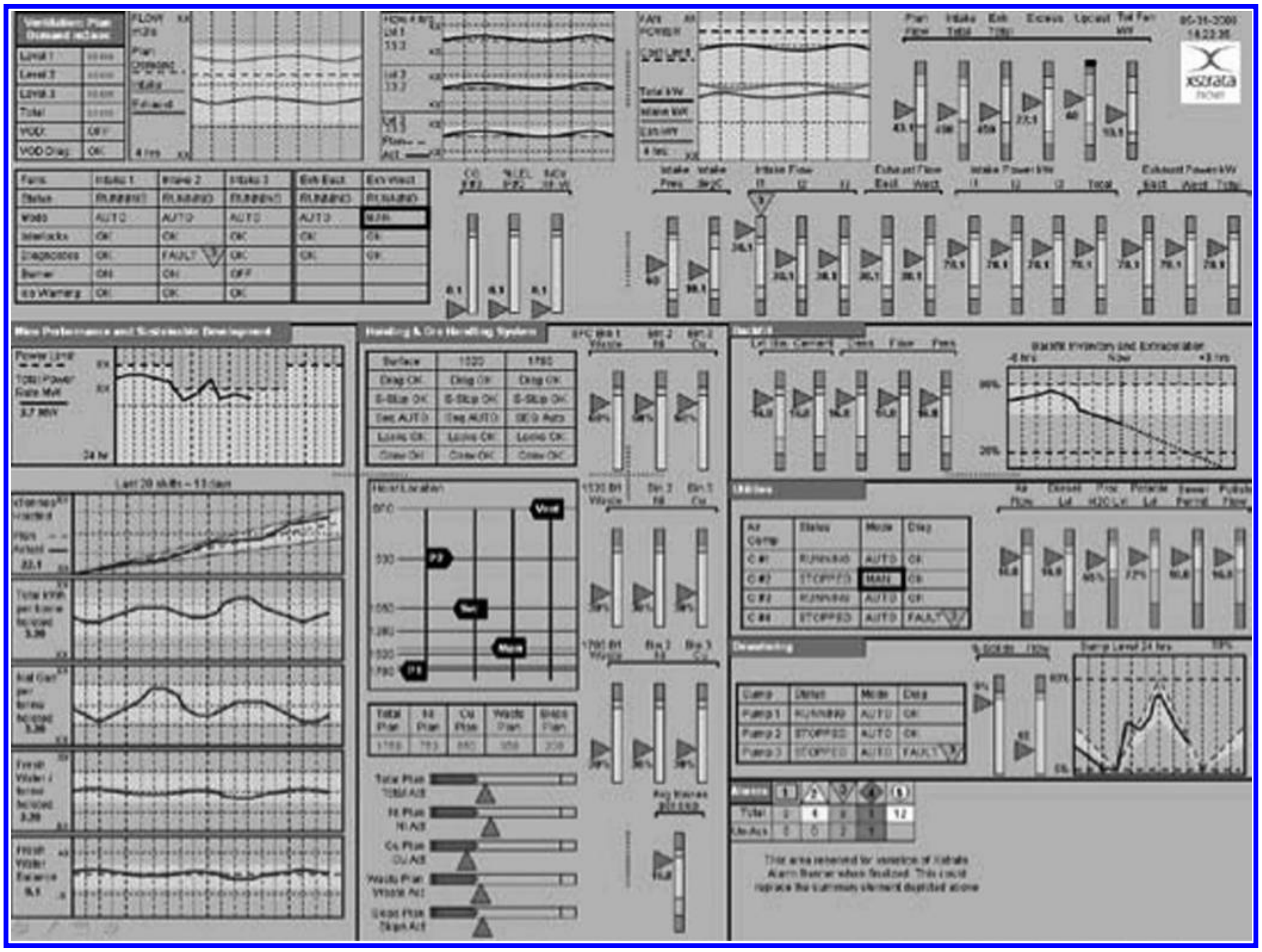


FIG. 55.17
Nickel Rim South Overview display.

The extrapolation made in Figure 55.20 is initially made through linear extrapolation, but will in the future be improved by calculating the balance between scheduled backfill delivery, and borehole pour consumption. Other predictive means such as modeling may be employed to further improve the prediction.

Peak Power Consumption Electrical power is typically priced variably throughout the day. High power costs during periods of peak demand make it desirable to lower consumption during these periods and divert this consumption to off-peak periods wherever possible. In Figure 55.21, two maximum demand limits of 15 MW and 18 MW have been defined. The lower of these limits applies during high power cost periods. Performance against this target is instantly obvious through the use of a trend control chart.

Revisions to Level 2 and Level 3 Displays

Owing to the length of the project, some of the process display had already been developed without consideration of the standards indicated above. In order to be consistent and to fully realize the vision of "process at a glance," these displays were revised to follow the new standards. As can be seen from Figures 55.22 and 55.23, these changes greatly enhance the effectiveness of the visualization.

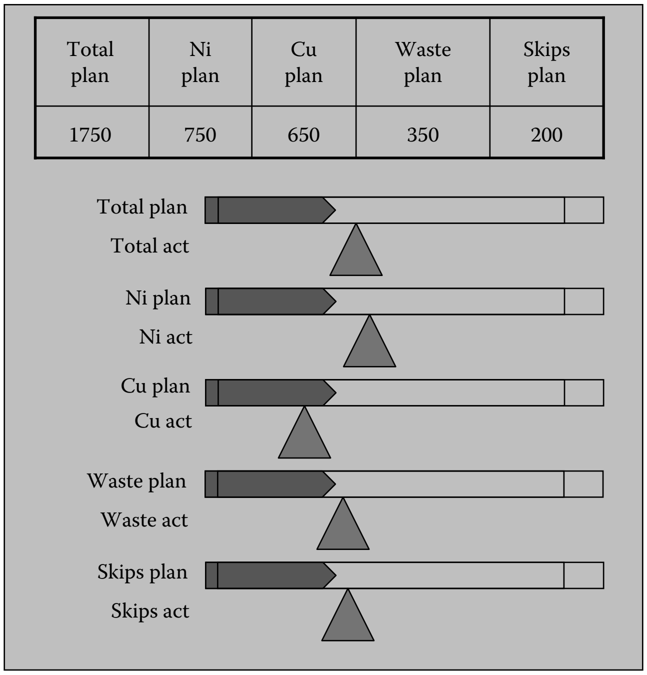
MINE SYSTEMS AUTOMATION AND APPLICATIONS

The establishment of a mine-wide SCADA system allowed the following advance process control strategies to be implemented on the following mine systems.

Hoists

The mine is equipped with four hoists. They are controlled by ABB variable-speed drives and associated controls:

1. *Main service hoist*: This two rope single deck Blair hoist is used for transport of persons and equipment to



Total plan	Ni plan	Cu plan	Waste plan	Skips plan
1750	750	650	350	200

FIG. 55.18
Production performance visualization.

all levels. Owing to the nature of the load is carries, it is typically manned by a cage tender, who operates the hoist using “elevator like” controls at each level.

2. *Auxiliary hoist*: This hoist is used for transport of up to 11 people at a time. It is fully automated and can be operated by the person using it.
3. *Ventilation shaft auxiliary hoist:* This hoist is not normally in use and is available as a second means of egress from the mine. It is fully automated and would be operated by the person/s using it.
4. *Production hoist*: This is a double-drum hoist with two skips. It is fully automated and hoists ore or waste from loading pockets at the 1,520 m and 1,700 m levels. The production hoist interfaces with Allan Bradley PLCs at both of these loading pockets.

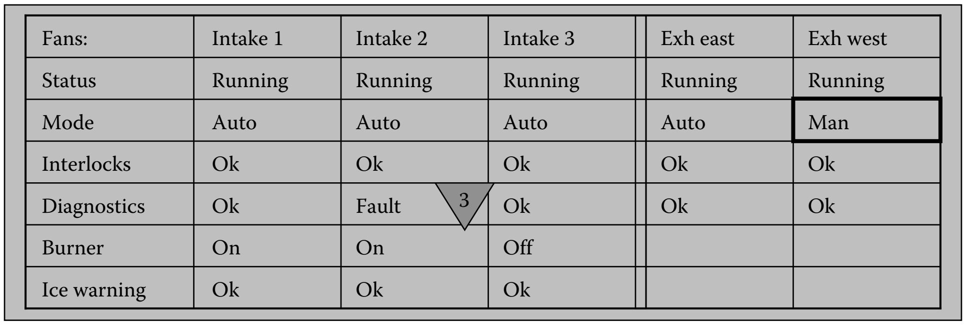
Ore Waste-Handling System

Three bins on surface are designated for copper ore, nickel ore, and waste rock. Underground bins located at the 1520 and 1700 m levels may contain any of the three materials depending on the material being mined. The material transfer system is fully automated via the following control strategies:

1. *Hoisted material selection*: Using the HMI system, the operator selects the bin from which material is to be hoisted and after having adjusted the hoist appropriately, starts the automatic sequence from the HMI (Figure 55.24).
2. *Skip overload protection*: Strategy that protects the skips from being overloaded, avoiding the risk of overflowing the skip and dropping material down the shaft.
3. *Surface bin high-level protection*: Through several high-level detection devices that prevent a skip from being loaded if there is no room to discharge this skip into the surface bin. A second protection exists, which prevents a loaded skip from being discharged into the surface bin under high-level conditions.
4. *Truck loading system*: Identifies the ore/waste trucks arriving at the surface bin house using RFID tags. A weighbridge is located directly under the truck loading area. A positioning system directs the truck driver to bin from which it is to be loaded. Once in position, the truck is automatically loaded by modulating the discharge arc gate and directing the truck to be moved forward in increments.

Dewatering

All mine water is collected in a 600 m^3 vertical sump at the 1,700 m level. From here it is pumped to surface via three 750 hp Feluwa positive displacement pumps. Each pump has a capacity of 250 gpm and up to two pumps can be operated simultaneously. Dewatering HMA display is illustrated in Figure 55.25. Advanced automatic control strategies implemented for these pumps include the following:



Fans:	Intake 1	Intake 2	Intake 3	Exh east	Exh west
Status	Running	Running	Running	Running	Running
Mode	Auto	Auto	Auto	Auto	Man
Interlocks	Ok	Ok	Ok	Ok	Ok
Diagnostics	Ok	Fault	Ok	Ok	Ok
Burner	On	On	Off		
Ice warning	Ok	Ok	Ok		

FIG. 55.19
Ventilation system status.

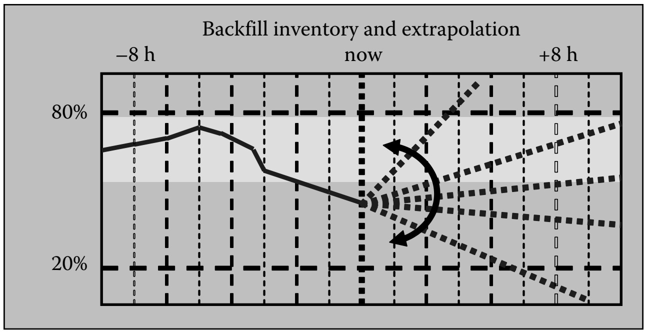


FIG. 55.20
Inventory trend display.

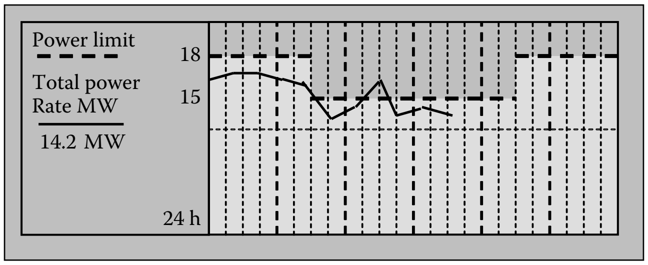


FIG. 55.21
Peak power consumption.

1. *Pump-at-night strategy*: Which allows the operations to take advantage of lower power costs during off-peak periods. The time of day that corresponds to high/low electricity cost periods is entered into the SCADA system, and the control strategy allows sump capacity to be utilized during high cost periods, and pumps down the sump during the lower cost period.
2. *Pump duty management strategy*: Which allows pump duty to be controlled to a duty ratio target entered into the SCADA system. This duty management avoids duty being shared equally amongst all pumps, which could lead to simultaneous wear-life failure of several pumps at the same time.
3. *Minimum run-time strategy*: Since these pumps are subject to significant wear from every start cycle, it is desirous to minimize the number of start/stop cycles in order to maximize their life span. This strategy calculates the expected run-time of a pump prior to start-up, and delays start-up until there is sufficient water in the sump to allow a predetermined run-time to be reached.

Ventilation

The ventilation shaft is equipped with two 4,000 hp Howden centrifugal surface exhaust fans, each controlled by an Allan Bradley PowerFlex variable frequency drive (VFD).

The main shaft is equipped with three 10 in. diameters, 450 HP Howden Buffalo Vaneaxial surface booster fans delivering fresh air to the main shaft at the adit level. Also equipped with PowerFlex VFDs, these fans maintain an upcast in the headframe. Each fan is equipped with three 37.0 MMBTHU direct-fired mine air heaters. During the winter, this air is heated using natural gas burners to avoid freezing of the shaft and headframe components. The HMI display of supply fan status is shown in Figure 55.26.

All mining sublevels include flow-through ventilation with fresh air from the access ramp reporting to a return air raise at the back of each level. Two return air drifts are used to deliver exhaust air from return air raises back to the exhausting ventilation shaft.

Mine ventilation can be automatically controlled using the following strategies:

1. *Headframe upcast flow controller*: Maintains a positive air flow up the mine headframe by regulating the speed of the three supply fans at the adit.
2. *Self-regulating underground air demand controllers*: Adjust fan speed to maintain a constant (negative) pressure at the exhaust fans under varying underground level damper positions.

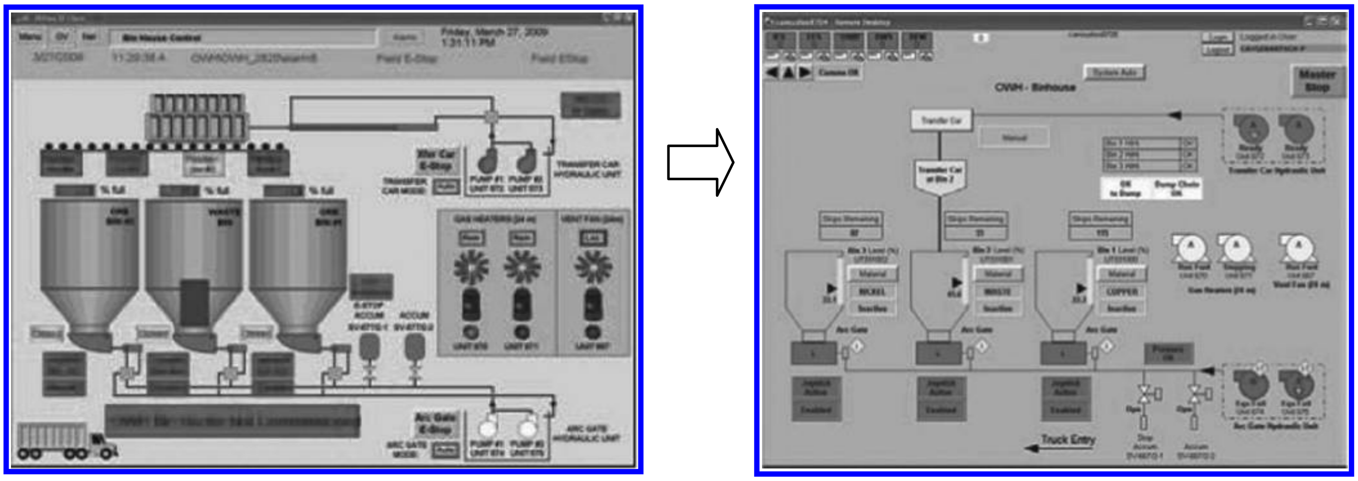


FIG. 55.22
Surface bin overview: before and after HMI revisions.

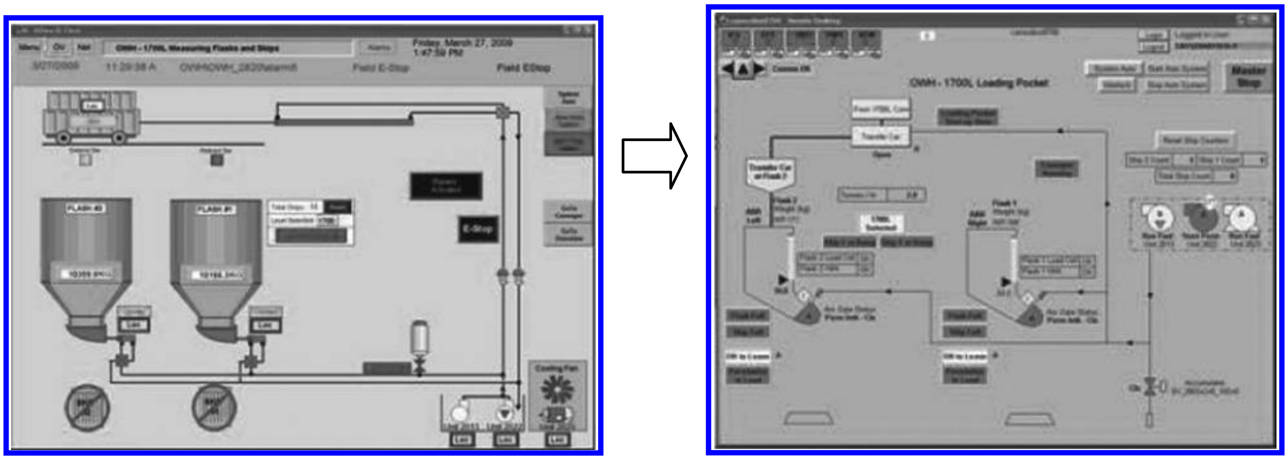


FIG. 55.23
Loading pocket detail display: before and after HMI revisions.

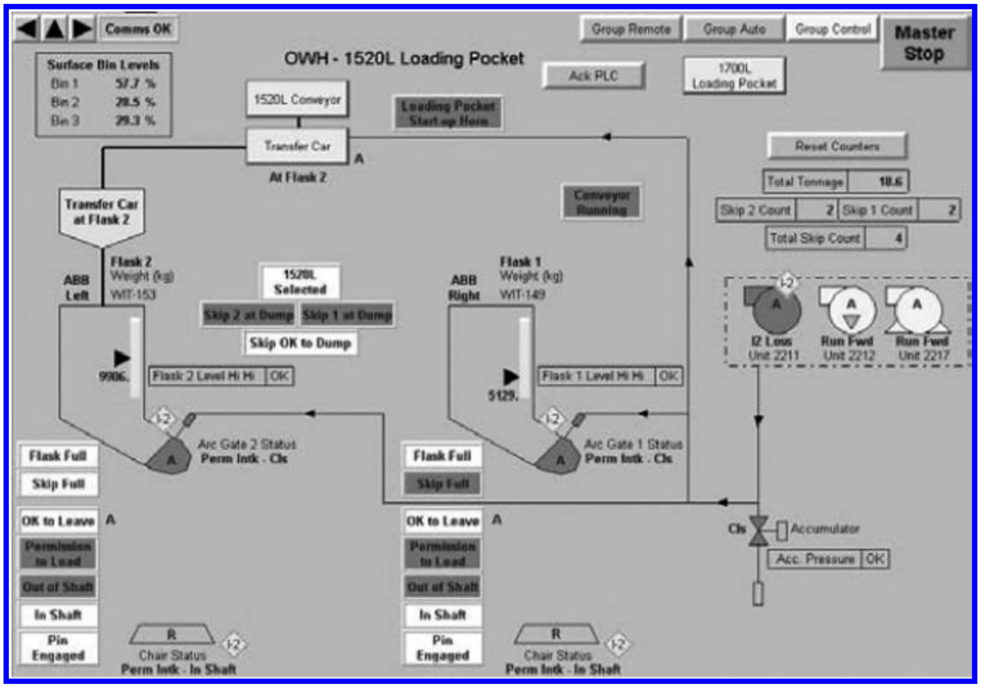


FIG. 55.24
Loading pocket display (requires interface with production hoist).

3. *Ventilation on demand system*: (Simsmart) Controls surface and underground fans and level dampers dynamically according to demand. This demand is determined in real-time according to an activity-based scheduler or through the mine tracking system, which indicates the location of miners and mobile equipment.

Fuel Transfer System

Diesel fuel for underground equipment is delivered to a surface storage tank. Transfer of fuel to the three main levels is automatically controlled through the following control strategies:

1. *Fuel demand*: To a level is initiated by a low level in an underground storage tank. This results in a 3001 fuel batch being sent to that tank. Fuel demand from each level is serviced in rotation maintaining the underground tanks in a full condition.
2. *System monitoring*: Strategy that alarms and shuts down the fuel transfer system if any of the following errors are detected:

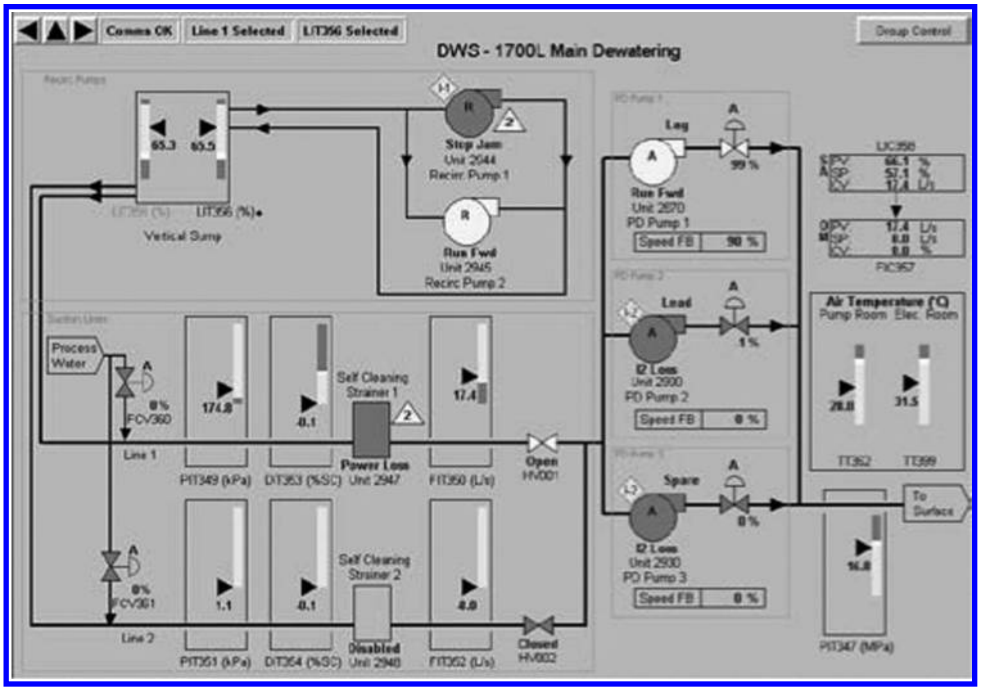


FIG. 55.25
Dewatering pump overview display (Note: Alarms only present on recirculation pump and strainer).

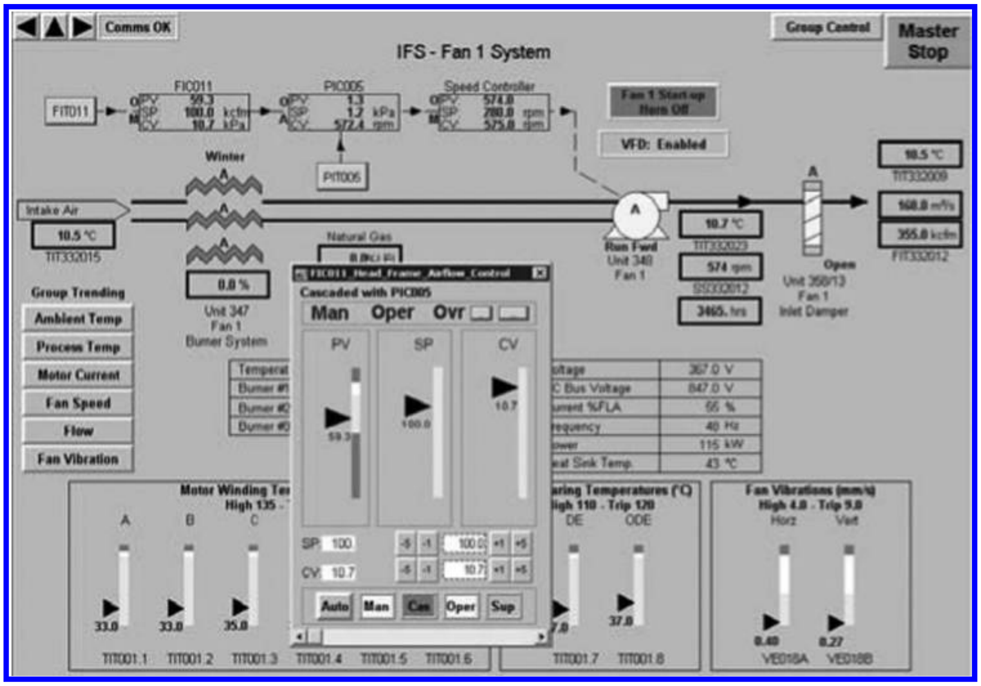
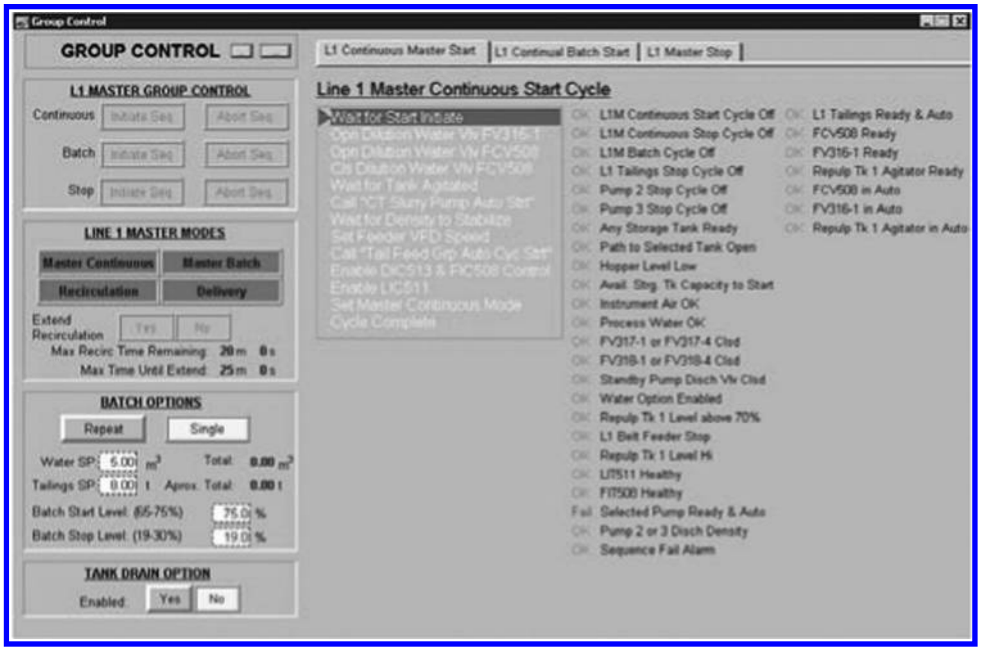


FIG. 55.26
Supply fan status including upcast flow controller.

a. Surface transfer pump run-time and measured flow do not correspond.
b. Fuel received at level when not demanded.
c. Rise in receiving tank level does not correspond to batch transferred.
d. Diverter valve position does not correspond with target level destination.

Backfill Plant

Mined out stopes are hydraulically backfilled to maintain stable ground conditions for further mining activity. Tailings from the Xstrata Nickel Strathcona Concentrator, which processes the mine ore, is returned in the ore trucks to the backfill plant. Processing of this material is fully automated;



Max Recirc Time Remaining 20 m 0 s
Max Time Until Extend 25 m 0 s

Water SP 5.00 m^3 Total 0.00 m^3
Tailings SP 0.00 t Aprox. Total 0.00 t
Batch Start Level (65-75%) 75.0 %
Batch Stop Level (19-30%) 19.0 %

Line 1 Master Continuous Start Cycle

Wait for Start Initiate
Opn Dilution Water Vlv FV316-1
Opn Dilution Water Vlv FCV508
Cls Dilution Water Vlv FCV508
Wait for Tank Agitated
Call "CT Slurry Pump Auto Str"
Wait for Density to Stabilize
Set Feeder VFD Speed
Call "Tail Feed Grp Auto Cyc Str"
Enable DIC513 & FIC508 Control
Enable LIC511
Set Master Continuous Mode
Cycle Complete

OK L1M Continuous Start Cycle Off
OK L1M Continuous Stop Cycle Off
OK L1M Batch Cycle Off
OK L1 Tailings Stop Cycle Off
OK Pump 2 Stop Cycle Off
OK Pump 3 Stop Cycle Off
OK Any Storage Tank Ready
OK Path to Selected Tank Open
OK Hopper Level Low
OK Avail. Strg. Tk Capacity to Start
OK Instrument Air OK
OK Process Water OK
OK FV317-1 or FV317-4 Clsd
OK FV318-1 or FV318-4 Clsd
OK Standby Pump Disch Vlv Clsd
OK Water Option Enabled
OK Repulp Tk 1 Level above 70%
OK L1 Belt Feeder Stop
OK Repulp Tk 1 Level Hi
OK LIT511 Healthy
OK FIT508 Healthy
Fail Selected Pump Ready & Auto
OK Pump 2 or 3 Disch Density
OK Sequence Fail Alarm

OK L1 Tailings Ready & Auto
OK FCV508 Ready
OK FV316-1 Ready
OK Repulp Tk 1 Agitator Ready
OK FCV508 in Auto
OK FV316-1 in Auto
OK Repulp Tk 1 Agitator in Auto

FIG. 55.27
Backfill plant sequence control faceplate.

requiring only a single "roving" operator to deal with clean-up and any issues that may arise. Field-mounted HMI screens as well as a wireless tablet carried by the plant operator, allows for alarm acknowledgment and any required plant interaction. The HMI display of the Backfill Plant sequence control faceplate is illustrated in Figure 55.27. Any interlocks that prevent sequence start are clearly indicated. The control strategies are as follows:

1. *Tailings receiving* plant utilizes traffic lights direct the trucks to one of two automated truck off-loading bays. A laser positioning system positions the truck over an off-loading bin and the truck driver discharges the tailings into the receiving hopper.
2. *Re-pulping* plant transfers the material in the receiving hopper and mixes it with water to a specified density before transferring to storage tanks. Designed to run continuously, the process may be required to start and stop automatically should the tailing trucks not be able to keep up with material demand.
3. *Mix Tank* plant transfers the material from the storage tank and mixes it with binders according to a recipe before discharging to the appropriate borehole.

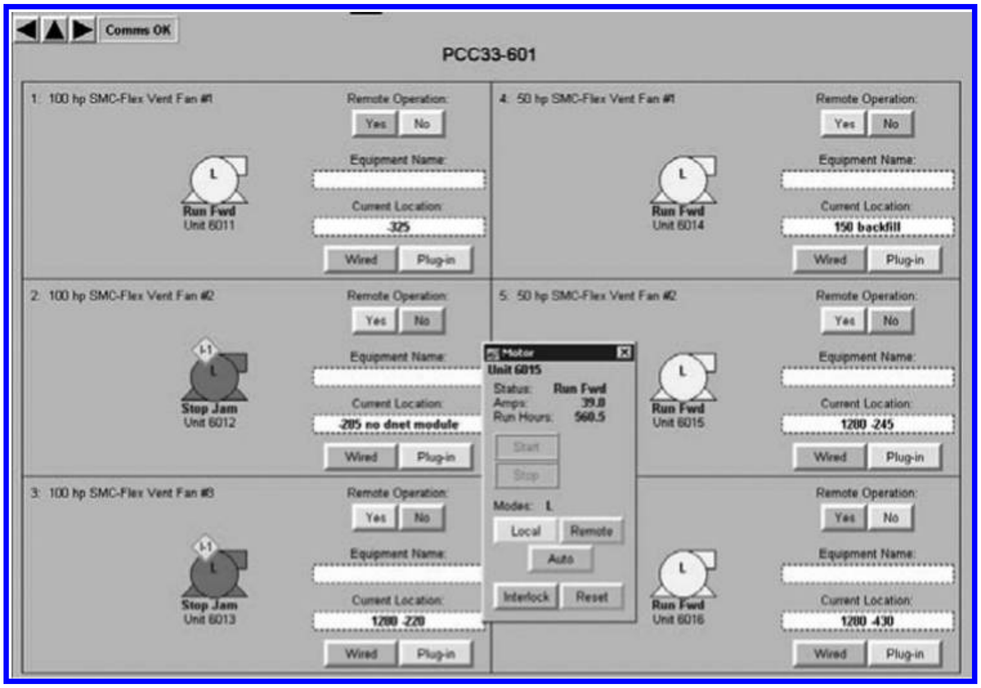
Underground Electrical Substation

Permanent underground Allen Bradley "Intellicenter" electrical substations are located at every shaft station on each level. They are of a standard design and can be monitored from the HMI through the use of DeviceNet connected to a shaft station PLC. Limited remote control functionality exists for remote operation of breakers.

Portable underground substations are required to support mining activities throughout the life of mine. These portable substations are comprised of four components:

1. *High voltage switch* (HVS) connects the substation to the incoming 13.8 kV mine power feeder. DeviceNet DSA modules monitor the status of the switchgear.
2. *Power system substation* (PSS) contains an 800 kVA transformer and associated switchgear to supply up to three 600 V power control centers.
3. *Power control center* (PCC) is used to allow (plug-in) connection of mining equipment to the substation. PCCs are designed of indifferent configurations depending on the required functionality. Electrical requirements vary depending on the mining activity at the time, which may be development, diamond drilling, blast-hole drilling, ventilation, etc. PCCs are moved from location to location as required. The HMI display of substation, PCC, power status is illustrated in Figure 55.28.
4. *Automation control center* (ACC) is the center of substation intelligence. They are connected to the mine communications network via fiber-optic cable. The substation DeviceNet is terminated to a PLC located in the ACC. This allows monitoring and control of all devices connected to the substation. In the event of loss of communications to surface, a local PLC CPU allows autonomous automated control of ventilations fans.

Status of all devices powered by a PCC is available on the HMI, which allows the following benefits to be reached:


PCC33-601

1: 100 hp SMC-Flex Vent Fan #1
Run Fwd
Unit 6011
Current Location: 325

2: 100 hp SMC-Flex Vent Fan #2
Stop Jam
Unit 6012
Current Location: 285 no dnet module

3: 100 hp SMC-Flex Vent Fan #3
Stop Jam
Unit 6013
Current Location: 1200 220

4: 50 hp SMC-Flex Vent Fan #1
Run Fwd
Unit 6014
Current Location: 150 backfill

5: 50 hp SMC-Flex Vent Fan #2
Run Fwd
Unit 6015
Current Location: 1200 245

Run Fwd
Unit 6016
Current Location: 1200 430

Motor
Unit 6015
Status: Run Fwd
Amps: 39.8
Run Hours: 560.5
Modes: L

FIG. 55.28
Substation (PCC) power status.

- Electrical maintenance personnel can monitor power demand remotely. Reported equipment trips and failure can be diagnosed remotely.
- Users of electrical equipment powered by the substations (e.g., drilling rigs) can monitor power draw and other parameters to determined if their equipment is functioning normally.
- System overloads and trip coordination relays can be monitored and adjusted remotely.

CONCLUSIONS

Through design of a well-integrated SCADA system, it is possible to integrate all automation aspects of a complete operation. Not only is vendor selection an important aspect of success, but the design philosophy must seek to exploit the optimization possibilities available.

The elements that led to the success of the Nickel Rim project in reaching this vision included the following:

- Not underestimating the challenge. Even when sticking with a single vendor, integration issues will occur, which will require reevaluation and, in some cases, redesign.
- Identification of experienced system integrators as well as vendor involvement in the design process.
- "Past" practice is not necessarily "Best" practice. There was an open mind to looking at better ways of doing things. Existing standards were not the point of departure.
- Designing flexibility into the infrastructure. Focus was on providing an "open" infrastructure, which could support any future (yet unidentified) application.
- Sticking to the plan.